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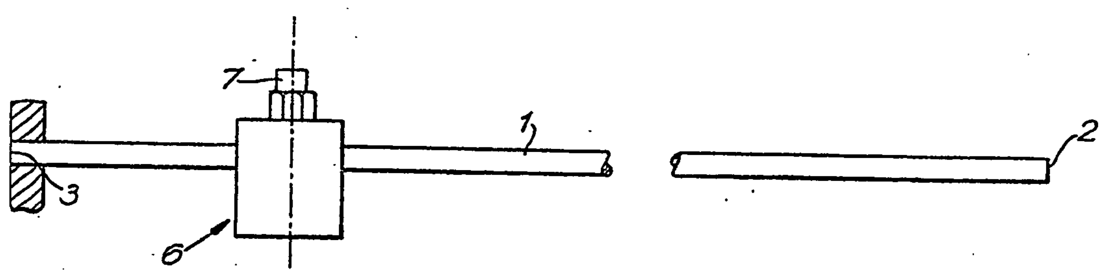
(54) Dynamic gas pressure measuring device

(57) Dynamic pressure fluctuations are sensed remotely by means of a transducer 7 communicating through a small hole in a wall of a duct 1 formed by a length of tube closed at one end 2 and open at its other end 3 to a space in which pressure is to be measured (for example, a high temperature region in a gas turbine engine). To ensure a resonance-free aperiodic frequency response characteristic, enabling dynamic pressure variations to be detected up to frequencies of several kHz, the hole is arranged closer to the open end than the closed end and an attenuation insert in the form of a rod or tube may be located adjacent the closed end. The transducer which may include an electrical strain gauge is protected from high temperature or other hostile conditions at the sensing point.

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

Fig.1.



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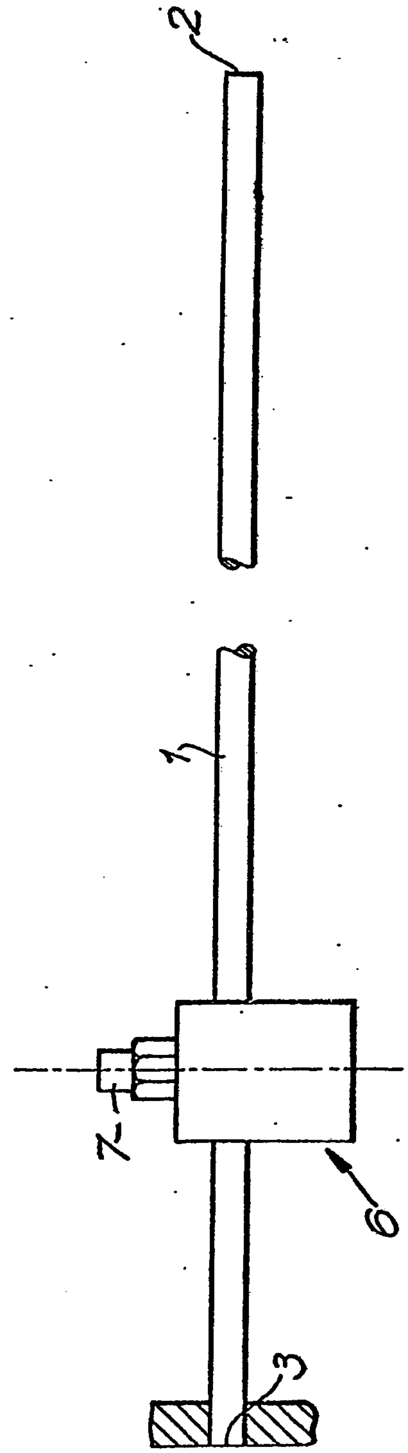
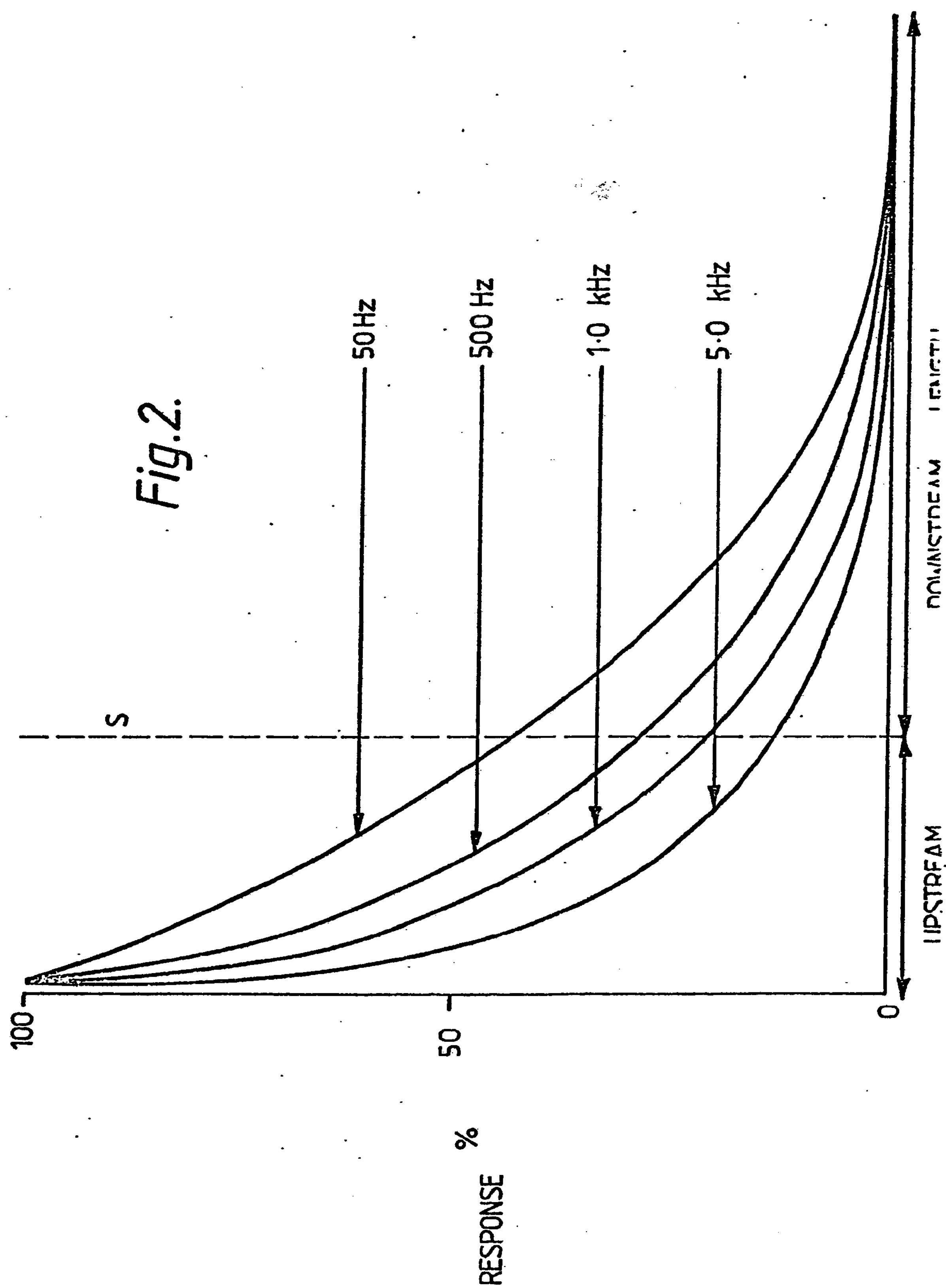


Fig.1.

Fig.2.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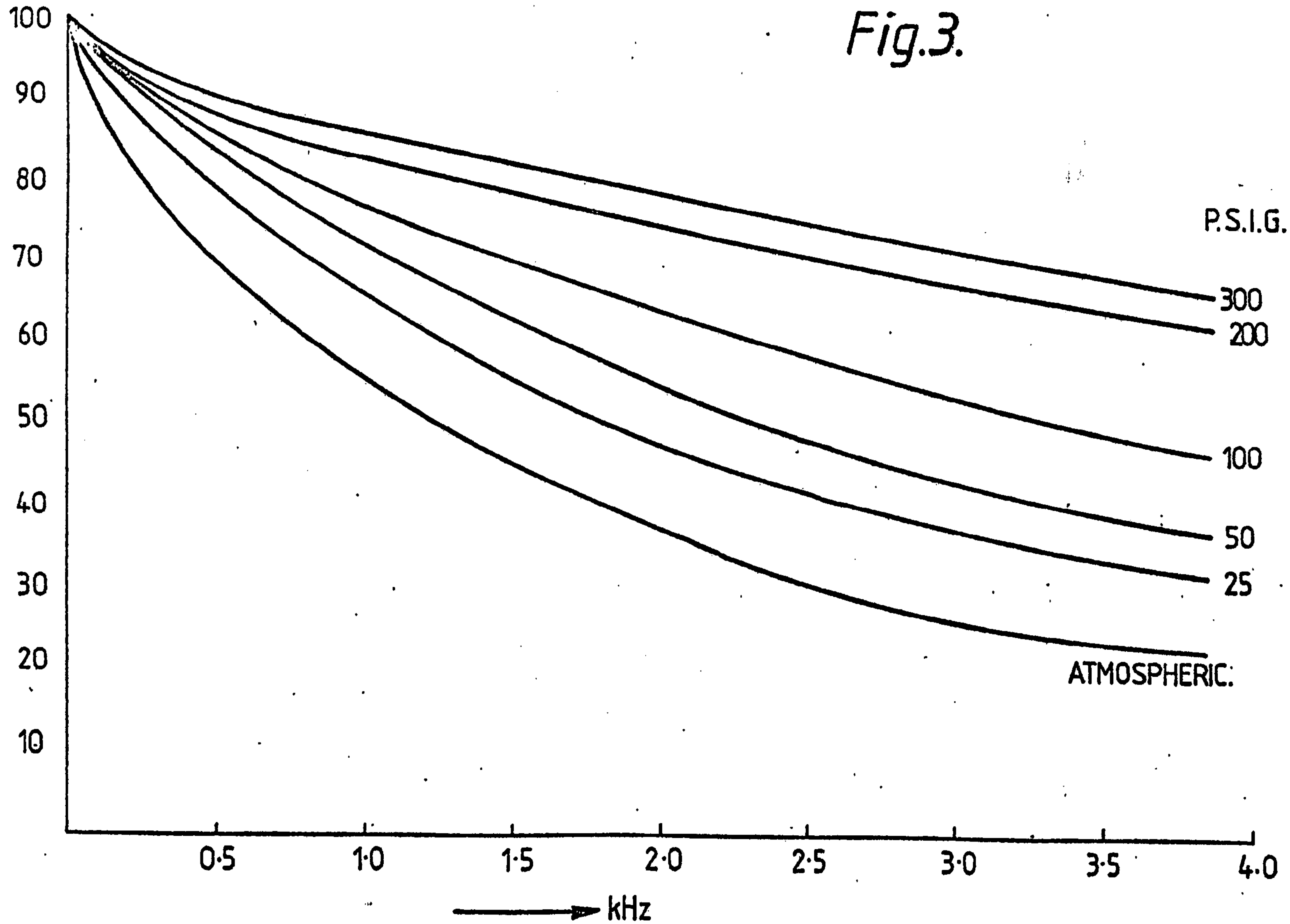
1·0 kHz
5·0 kHz
S
100
50
0
RESPONSE %
UPSTREAM
DOWNSTREAM

Fig.3.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2·0
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kHz
P.S.I.G.
300
200
100
50
25
ATMOSPHERIC.

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Fig.4.

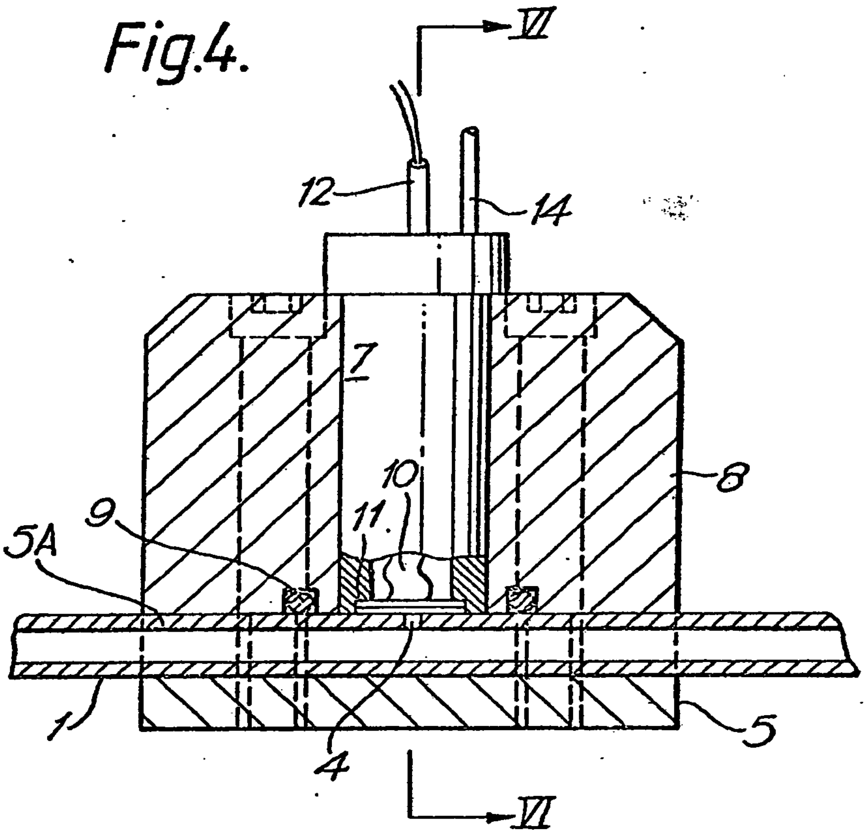


Fig.5.

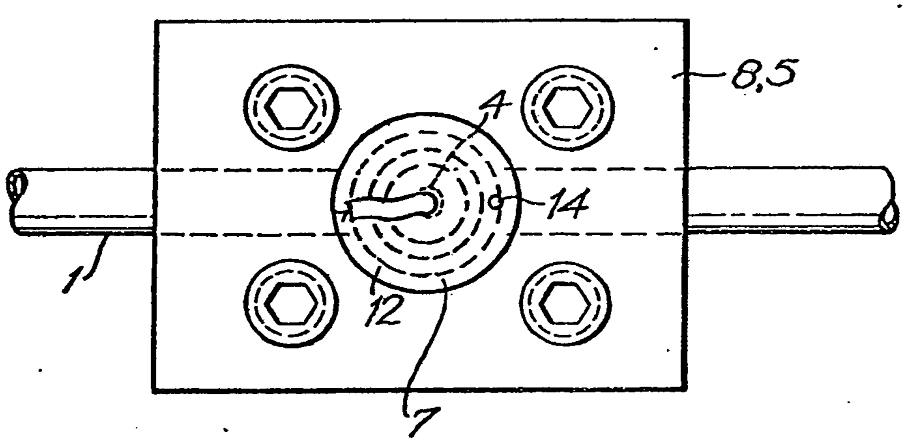
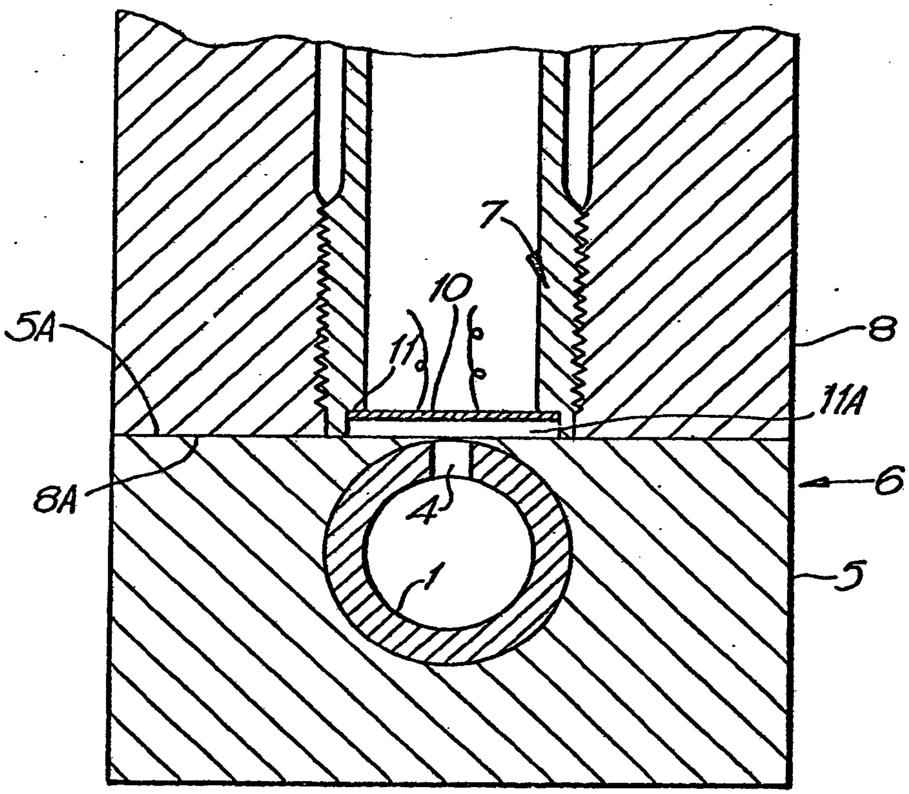


Fig.6.



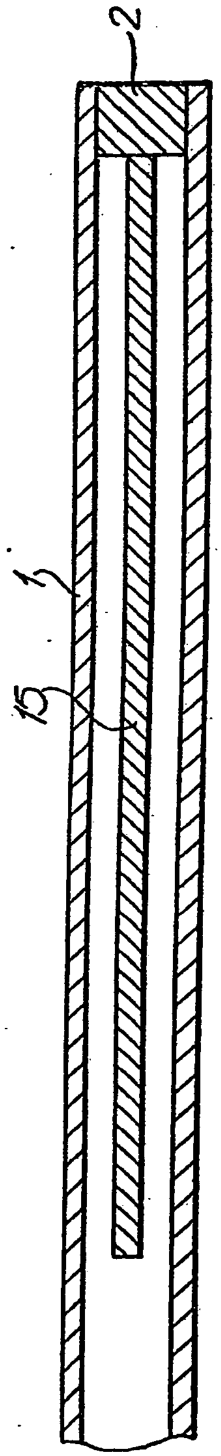


Fig.7.

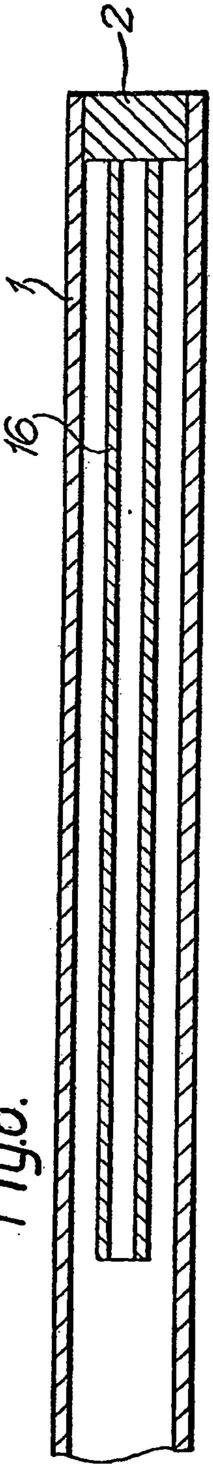


Fig.8.

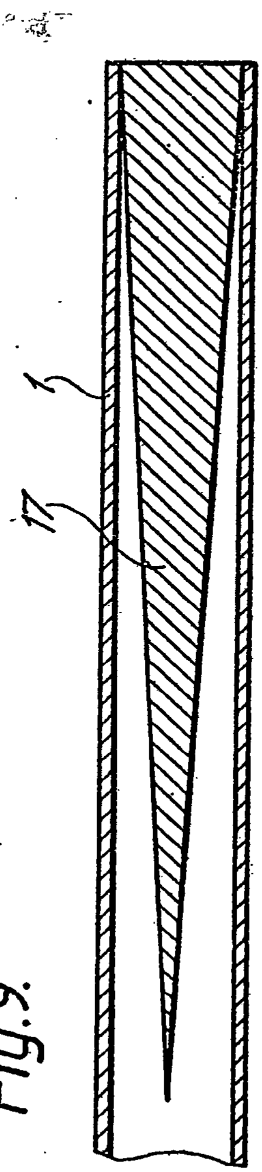


Fig.9.

SPECIFICATION

Dynamic gas pressure measuring device

This invention relates to pressure measuring devices, particularly devices for measuring dynamic pressure in a gas remotely from a pressure sensing point.

A problem which arises in many industrial applications is that of measuring dynamic pressures, that is, pressure fluctuations, in regions of high gas temperature and/or high static pressure, such as occur, for example, in gas turbine engines.

An object of the present invention is to provide a pressure measuring device capable of measuring dynamic pressure changes in a gas remotely from a pressure sensing point, over a range of frequency variation, and with minimal risk of damage to the sensor as a result of high temperatures or other hostile conditions at the sensing point.

According to the invention there is provided a pressure measuring device for measuring dynamic pressure fluctuations in a gas remotely from a pressure sensing point, comprising a system formed by a duct closed at one end and communicating at its other end with the pressure sensing point, and a pressure transducer communicating with a hole in the wall of the duct intermediate the two ends of the duct for measuring the dynamic pressure in the duct, the system configuration, including the length of the duct on each side of the transducer, being such that the frequency response characteristic of the system is free of resonances over a useful range of frequencies of pressure fluctuation.

Since the duct in which the pressure measurements are made is closed at one end there is no steady flow of gas along the duct, and accordingly the transducer is protected from high gas temperatures at the sensing point.

Preferably the length of the duct between the hole in the wall of the duct and the closed end of the duct is greater than the length of the duct between the said hole and the sensing point. It can be arranged that if the duct has a sufficient length in relation to its internal diameter dynamic pressure fluctuations along the duct are attenuated to substantially zero amplitude at the sealed end of the duct, so that the duct is for practical purposes equivalent to a tube of infinite length downstream of the position at which the transducer is mounted. This ensures a smooth frequency response free of resonances over an acceptable range of frequencies of pressure fluctuation.

The pressure transducer preferably includes a diaphragm mounted adjacent the hole in the duct wall and defining a fluid-tightly sealed chamber in communication with the said hole, and means responsive to deformation of the diaphragm as a result of the dynamic pressure to be measured to provide an electrical output representative of said dynamic pressure.

It is important that the hole in the duct wall at which the transducer is mounted should present a negligible discontinuity to the pressure fluctuations in the duct. Thus the cross-sectional area of the hole in the duct wall should be substantially smaller than the internal cross-sectional area of the duct. In one embodiment of the invention the duct has a flattened cross-section in the portion in which the transducer is mounted, the transducer itself being located flush with one of the flat inner wall surfaces of the duct.

The duct may in practice comprise a sufficient length of metal or plastics tubing having a sealed termination at the closed end. For some practical applications it may be impractical to have an adequately long length of uniform cross-section tubing downstream of the region at which the transducer is mounted, in which case pressure wave attenuation means may be disposed in the duct between the hole in the duct wall and the closed end. Such attenuation means should, of course, be essentially non-reflective. In one embodiment of the invention the attenuation means may comprise a length of rod or tube inserted into the duct between the closed end and the hole in the duct wall. Alternatively, the attenuation means may be formed by a region in which the internal air space within the duct tapers in cross sectional area towards the closed end of the duct. The tapered cross-sectional area may be defined by an insert within the duct tapering in cross-section from the closed end of the duct to a point disposed between the closed end and the hole in the duct wall.

The invention will be further described, by way of example, with reference to the accompanying, purely diagrammatic drawings, in which:

Figure 1 is a schematic illustration of a pressure measuring device according to one embodiment of the invention;

Figure 2 illustrates graphically a typical set of dynamic pressure attenuation curves for pressure fluctuations along the length of the duct of the device shown in Figure 1;

Figure 3 illustrates graphically a set of frequency response curves for dynamic pressure variations at different static pressures as measured by the transducer of the device shown in Figure 1;

Figure 4 is a diagrammatic axial section, on an enlarged scale, of the transducer and part of the duct of the device shown in Figure 1;

Figure 5 is a diagrammatic plan view of the transducer and portion of the duct shown in Figure 4;

Figure 6 is a cross-section taken on line VI—VI in Figure 4, and

Figures 7, 8 and 9 are diagrammatic axial sections of downstream end portions of the duct of the device shown in Figure 1, illustrating different forms of attenuation means adjacent the closed end of the duct.

The device shown in Figure 1 is adapted for the measurement of dynamic pressure fluctuations in a gas at high temperature and static pressure, for example at a point in the turbine of a gas turbine

engine. The device comprises a long pressure duct formed from a length of metal tubing 1 closed at one end by a sealed termination 2 and open at its other end 3, at which the tubing 1 is in communication with a pressure sensing point at which the pressure to be measured is sampled.

The wall of the tubing 1 forming the sampling duct has a smooth internal bore and is perforated intermediately to ends of the duct by a small hole 4 (Figures 4 to 6) having a diameter which is significantly less than the internal diameter of the sampling duct itself, so as to constitute a negligible discontinuity as far as dynamic pressure fluctuations in the duct are concerned. Typically, for a duct formed by 3 mm outside diameter tubing the hole 4 would have a diameter of 0.5 mm or less. The hole 4 is located nearer the open sampling end 3 of the tubing 1 than the closed end 2. In a typical practical embodiment the length of the sampling duct upstream of the hole 4, that is, between the hole 4 and the open end of the duct, would be 0.5 metres, while the length of the tubing 1 between the hole 4 and the closed end 2 would be 18 metres for uniform cross-section tubings.

The portion of the tubing 1 in which the hole 4 is formed is located in a base portion 5 (Figure 6) of a "transition block" 6 (Figure 1) in which a pressure transducer 7 is mounted. The base portion 5 has a through-bore in which the tubing 1 is a gas tight fit, the hole 4 in the wall of the tubing opening into a face 5A of the base portion 5 against which a corresponding face 8A of a transducer block 8 is sealed, for example by means of an O-ring located in an annular groove 9 and surrounding the hole 4 concentrically in the assembled position of the block 8 on the base portion 5.

The transducer 7 has a diaphragm 10, shown in broken outline in Figure 4, which is supported peripherally against an annular lip 11 defining a small chamber 11A which communicates with the hole 4 in the wall of the tubing 1 when the transducer block 8 is assembled on the base portion 5 so that the diaphragm 10 is exposed to the pressure fluctuations transmitted to it through the hole 4 from the interior of the tubing 1.

Pressure fluctuations in the tubing 1 are sampled at the hole 4 and are transmitted to the diaphragm 10. The pressure fluctuations are converted into electrical signals by means of suitable transducer elements (not shown) for example strain gauges provided on the face of the diaphragm 10 opposite that which is exposed to the hole 4. The electrical signals from the transducer elements associated with the diaphragm 10 are taken from the transducer 7 through leads 12, and a reference pressure is applied to the opposite face of the diaphragm 10 from that which is exposed to the hole 4 through a reference pressure inlet 14.

The dynamic pressure fluctuations along the length of the sampling duct formed by the tubing 1 decay approximately exponentially along the length of the sampling duct, as illustrated graphically in Figure 2, in which the position of the hole 4 at which the pressure in the duct is sampled is indicated by a line S. The attenuation of the higher frequency pressure fluctuations is greater than that of the lower frequency fluctuations, but in practice this does not impair the effectiveness of the device, since the transducer 7 can have an inherently high signal/noise ratio.

The frequency response of the transducer located at the sampling hole 4 for different frequencies of pressure fluctuation is illustrated diagramatically in Figure 3 for different static pressures. It will be seen that the frequency response is substantially aperiodic and free of resonances over a useful range of frequency variation.

In order to reduce the total length of the sampling duct downstream of the transducer 7, that is, between the sampling hole 4 and the closed end 2, various types of attenuator device may be located within the downstream section of the tubing 1. Three examples of such attenuator are illustrated diagrammatically in Figures 7, 8 and 9. In Figure 7, a rod 15 is inserted coaxially into the downstream end of the tubing 1, from the closed end 2 of the latter, while Figure 8 illustrates a similar arrangement using a coaxial length of tubing 16 of smaller outside diameter than the internal diameter of the tubing 1 itself. An alternative form of attenuator, illustrated diagrammatically in Figure 9, consists of a tapered insert 17 forming the closed end of the tubing 1 and tapering to a point between the closed end and the sampling hole 4, so as to form an air passage within the tubing 1 of gradually tapering cross-section area and increasing surface area. An equivalent arrangement to this, which could also be used, would utilise an insert of cylindrical shape inserted into a frusto-conical end portion of the tubing 1 tapering in diameter towards the closed end where the tubing 1 would be sealed to the surface of the insert.

In a typical practical embodiment of the device according to the invention, pressure fluctuations at frequencies up to several kilohertz were measurable by means of a transducer 7 cooperating with a sampling hole 4 located as described above, the pressure fluctuations being at mean pressure levels between atmospheric and 300 p.s.i.g.

CLAIMS

1. A pressure-measuring device for measuring dynamic pressure fluctuations in a gas remotely from a pressure sensing point, comprising a system formed by a duct closed at one end and communicating at its other end with the pressure sensing point, and a pressure transducer communicating with a whole in the wall of the duct intermediate the two ends of the duct for measuring the dynamic pressure in the duct, and system configuration, including the length of the duct on each side of the transducer, being such that the frequency response characteristic of the

system is free of resonances over a useful range of frequencies of pressure fluctuation.

2. A device according to Claim 1, in which the length of the duct between the hole in the wall of the duct and the closed end of the duct is greater than the length of the duct between the said hole and the sensing point.

3. A device according to Claim 1 or Claim 2, in which the pressure transducer includes a diaphragm mounted adjacent the hole in the duct wall and defining a fluid-tightly sealed chamber in communication with the said hole, and means responsive to deformation of the diaphragm as a result of the dynamic pressure to be measured to provide an electrical output representative of said dynamic pressure.

4. A device according to any one of the preceding claims, in which the cross-sectional area of the hole in the duct wall is substantially smaller than the internal cross-sectional area of the duct.

5. A device according to any one of the preceding claims, in which the duct has a flattened cross-section in the portion in which the transducer is mounted, the transducer being located flush with one of the flat inner wall surfaces of the duct.

6. A device according to any one of the preceding claims, including pressure wave attenuation means disposed in the duct between the hole in the duct wall and the closed end.

7. A device according to Claim 6, in which the attenuation means comprise a length of rod or tube inserted into the duct between the closed end and the hole in the duct wall.

8. A device according to Claim 6, in which the attenuation means are formed by a region in which the internal air space within the duct, tapers in cross-sectional area towards the closed end of the duct.

9. A device according to Claim 9, in which the tapered cross-sectional area is defined by an insert within the duct tapering in width from the closed end of the duct to a point disposed between the closed end and the hole in the duct wall.

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